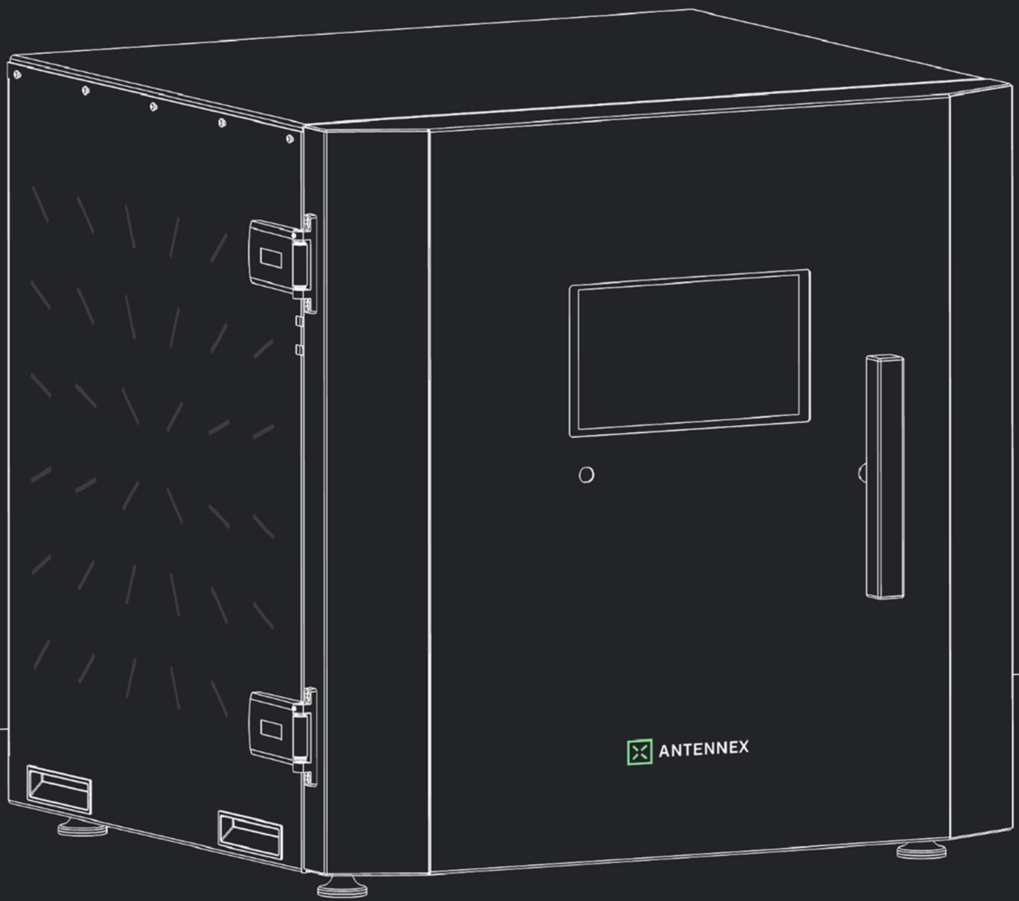
APPLICATION NOTE

Accurate and Fast Power Characterization at a Fixed Frequency

Using Zero Span Mode on a Spectrum Analyzer



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Introduction

The use of active phased array systems is growing rapidly for different kinds of communication and radar applications. Because of the high level of integration of active components with the radiating elements, RF characterization and test engineers are now also confronted with over the air (OTA) measurement tasks besides the well-known conductive tests. Therefore it is important to make the OTA characterization and test processes as similar as possible to conductive testing. This is realized with The Wireless Connector® for an important set of power performance factors which are key for the proper operation of the device under test (DUT) ([1]).

This application note focuses on the accurate and fast measurement with The Wireless Connector® of the total radiated power (TRP) of devices, radiating at a given frequency, using a spectrum or vector signal analyzer in zero span mode. Both instruments are further referred to as spectrum analyzer. In case of a vector signal analyzer it is assumed that the absolute value of the IQ signal is used.

The Wireless Connector® is a test chamber, consisting of a reverberation chamber, in contrast to an anechoic chamber, equipped with measurement software, touch screen for immediate interactive use and remote control capability for integration in external test programs. The Wireless Connector® is optimized for different types of power characterization, including TRP and noise characterization. Compared to the use of an anechoic chamber, the reverberation chamber accelerates the power characterization substantially while improving the accuracy and simplifying the measurement process.

As in many cases, the DUT only needs to be characterized at a given transmitting frequency, the OTA characterization with The Wireless Connector® is accelerated by using the zero span mode on the spectrum analyzer, avoiding a frequency sweep while instead measuring the power as function of time at a fixed frequency.

This application note explains how to setup the zero span mode on the spectrum analyzer in combination with the DUT and the settings for The Wireless Connector® while providing technical insight in these settings and illustrating their impact.

First the application note explains in short the difference between the anechoic and reverberation chamber. This leads to the use of stirrers in the reverberation chamber and settings of the zero span mode. To achieve accurate absolute power measurements, a relatively simple calibration process is explained in a nutshell. Finally a practical use case, based on a commercially available evaluation kit, illustrates the concrete steps of the characterization process.

The Test Chamber

Over the air characterization is typically done in a chamber presenting a controlled environment to the device under test. Two main types of test chamber are available: the anechoic and reverberation chamber.

The anechoic chamber

In an anechoic chamber the propagating waves, radiated by the phased array under test or any other radiating DUT, are absorbed by absorbative walls of the chamber to get as close as possible to radiation in free space.

Measurement probes are put in the chamber, which need to be aligned carefully and accurately with the DUT to measure the fields at different known positions. The higher the frequency, the larger the position and measurement uncertainty and the more difficult to align probe and DUT.

The reverberation chamber

In a reverberation chamber the propagating waves, radiated by the phased array under test or any other radiating DUT, are reflected by reflective walls of the chamber, creating standing waves. All radiated power is contained in the chamber. Nevertheless these reflections, the impact on the regular performance of the DUT is minimal thanks to the smart construction of the reverberation chamber, avoiding direct reflections and taking advantage of the inherent chamber losses.

A reference antenna, part of the measurement system, is put in the chamber to probe (DUT in transmit mode) or generate (DUT in receive mode) fields. Thanks to the principle to measure with a reverberation chamber, the position of the reference antenna and DUT are not important and will not impact the accuracy of the measurement results. This is a major benefit compared to the anechoic chamber.

To characterize the power performance of the DUT, the reflective properties of the chamber are changed by rotating mechanically reflective stirrers (Fig. 1) such that the standing waves shift in position and direction presenting different constructive and destructive wave interferences to the reference antenna, similar at almost any location in the chamber. At higher frequencies, these changes occur more quickly as the stirrers rotate. At lower frequencies, a larger rotation angle is required to produce significant variations in amplitude and phase.

Thanks to an ingenious shape of the chamber and of the stirrers, these changes in the electromagnetic fields can be considered as a random process when being sampled. By properly averaging the different power measurements, one extracts accurately a measure for the power performance of the DUT. These measurements can be performed with a spectrum analyzer at a specific frequency or as function of frequency.

Fig. 1. Vertical stirrer inside The Wireless Connector®

Stirring modes

The Wireless Connector® is foreseen of two stirrers: a horizontal and vertical stirrer, stirring the fields in all positions and directions thanks to the horizontal and vertical orientation of these stirrers. Two different stirring modes can be used during the measurement process: stepped and continuous stirring mode.

Stepped stirring mode

In stepped stirring mode, both stirrers are positioned at a certain rotation angle and a measurement is performed before going to the next position. The starting position of the stirrer is arbitrary and not fixed. The stirrers are typically positioned with increasing angle and the step in angle is large enough to randomize the fields and to make sure that the measurements at the different stirrer positions are uncorrelated. The uncorrelated measurements at the different positions are then properly averaged resulting in an accurate power performance factor of the DUT. The uncertainty on this power measurement can be predicted theoretically using statistics. Accuracy can be improved by taking more measurements.

This mode is typically used with frequency-swept spectrum analyzer measurements where the frequency sweep is performed per position of the stirrers.

Continuous stirring mode

In contrast to the stepped stirring mode, the stirrers rotate continuously in continuous stirring mode. Measurements are performed while both stirrers rotate, effectively sampling or measuring the fields at different stirrer positions. The sampling process must be chosen adequately to maintain the random character. Sampling too fast compared to changes in the electromagnetic fields due to the continuous stirring, can lead to a large set of correlated samples. They cannot be considered as the result of a random process and do not contribute to the improvement of the power measurements. Therefore one must make sure to collect enough uncorrelated samples. Sampling too slow is beneficial for the randomization process but would reduce the measurement speed unnecessarily.

The fields in the chamber track the rotation of the stirrers instantaneously, as the rotation speed is slow compared to the fast reaction time of the fields in the chamber. Therefore the results using the continuous stirring mode will correspond to similar measurements performed with a stepped stirrer.

This mode is ideal to characterize the power performance of a radiating DUT at a single frequency using the zero span mode of a spectrum analyzer, as explained in this application note.

Continuous stirring mode and zero span mode of the spectrum analyzer

The principle

As mentioned, in many use cases one wants to characterize the radiating device at one fixed known frequency.

The continuous stirring mode of both the vertical and horizontal stirrer is used to speed up the measurement process. This mode eliminates the overhead of the stepped stirring mode while one samples the changing electromagnetic fields with the spectrum analyzer mode in zero span mode. The power is measured at one frequency as function of time and the data is processed into one power measurement at the given frequency. To measure the power at the given frequency accurately, it is important to collect enough uncorrelated (random) samples of the changing field strength. The power at the given frequency can be derived from these samples by properly averaging. Also the uncertainty on the power can be estimated using the set of samples. This uncertainty is related to the precision of the measurement. The accuracy will be determined by the calibration.

The total uncertainty on the power measurement is a combination of different contributing uncertainties:

- The power measurement is based on a statistical process thanks to the change in position of the stirrers and contributes by itself a certain uncertainty that can be reduced by increasing the number of uncorrelated samples
- When the power of the DUT itself is fluctuating for the selected settings, these fluctuations are added to the uncertainty of the measured quantity
- The uncertainty on the correction coefficients resulting from the factory chamber calibration and the additional chamber calibration performed by the user
- The uncertainty on the correction coefficients resulting from the external calibration of the hardware from the reference antenna feedthrough panel to the spectrum analyzer

The settings of the continuous stirring mode

The position of vertical and horizontal stirrer determine the electromagnetic fields in position and direction, presenting fields with destructive and constructive interference to the reference antenna as to any other location.

If both stirrers are turning at the same speed, they will rotate synchronously. Suppose both stirrers rotate at 5 rotations per minute (RPM), they both do one turn and will be back in the same position in 12s. As such, after 12s no measurements can be made providing new information. Instead if one selects the rotation speeds differently, it takes longer before they are together back in the same position, repeating the same sequence again. Suppose one stirrer rotates at 19 RPM and the other stirrer at 20 RPM, they both are back in same position in one minute. One minute is plenty of time to collect uncorrelated measurements. A measurement is typically performed in seconds to provide an accurate power measurement.

19 RPM and 20 RPM are advised respectively as preferred values for both stirrers. Using The Wireless Connector® , these settings can be set via the graphical user interface (GUI) [2] or via remote control capability [3].

The settings of the spectrum analyzer

The spectrum analyzer is connected via external RF cabling, RF adapters and the reference antenna feedthrough panel to the reference antenna inside the reverberation chamber, probing the radiated fields from a DUT (Fig. 2).

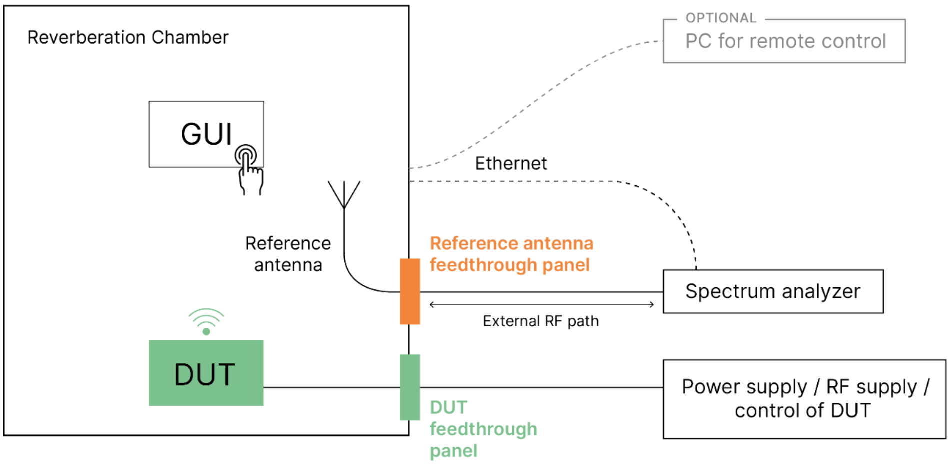

Fig. 2. Setup of The Wireless Connector

For absolute power measurements, The Wireless Connector® needs to be calibrated. The best practice is to calibrate the chamber first at the desired frequency or frequency span before optimizing the settings of the spectrum analyzer in combination with the radiating DUT. The reason is that at the end of the calibration cycle, the DUT must be positioned in the chamber at its measurement position, within the designated DUT region of The Wireless Connector® (Fig. 3.) with all its interfacing cables going through the DUT feedthrough panel. As such the DUT does not need to be moved anymore after the calibration.

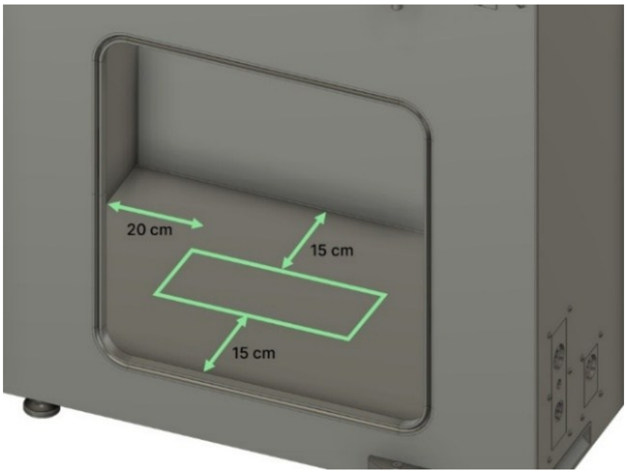

Fig. 3. Indicative DUT placement region. The DUT should not be placed too close to metal surfaces, and the DUT should be radiating upwards

It can be helpful to mount the DUT in the chamber before calibration, in order to perform some initial frequency-swept measurements with the spectrum analyzer. This allows you to identify the radiating frequency or frequencies of the DUT, and decide on the appropriate frequency range to be considered during calibration.

Once calibrated, the settings of the spectrum analyzer for zero span mode are optimized while interacting directly with the spectrum analyzer. The chamber corrections are not needed. Once the settings are determined, they can be used with the GUI or via the remote control capability of The Wireless Connector® using the advanced settings for the spectrum analyzer ([2]).

The spectrum analyzer settings are explained step by step in the order one typically would apply them.

Video Bandwidth

The video bandwidth on the spectrum analyzer needs to be set always equal or larger than the resolution bandwidth (RBW) to avoid smoothening the display trace. One can set it safely to the largest allowed bandwidth.

> Video bandwidth ≥ resolution bandwidth
>
> Video bandwidth set to maximum possible bandwidth is allowed

Detector mode and averaging type

The spectrum analyzer typically has different detector modes and averaging types to optimize feedback on the display of the instrument for different types of signals and for different measurement purposes e.g. measuring a sine wave signal, characterizing noise, spurious detection.

In this application note the goal is to accurately measure power of a DUT at a given frequency. The measured signals, proportional to the fields, are sometimes small (destructive interference) and sometimes large (constructive interference) depending on the position of the stirrer.

As detector mode, “Sample” or “Averaging” mode are valid choices. In many cases both are interchangeable and the difference in result will be very minimal. It is advised to put the detector mode into averaging mode, combined with the proper averaging type, to take advantage of the averaging of the spectrum analyzer as it samples faster than the equivalent sampling time defined by time span and number of points.

It is important to select the proper averaging type when the “Average” detector mode has been selected. Different averaging types e.g. average power, log average power, voltage average, are available. As small and large signals are equally important, log average power is avoided and as the final figure of merit is a power quantity, it is strongly advised to use average power (RMS).

Detector mode : Average

Averaging type : Power average (RMS)

Center Frequency

To confirm or determine the radiating frequency of the DUT, the stirrers should not move and the spectrum analyzer is put in frequency sweep mode selecting a center frequency and span, able to identify the radiating frequency or frequencies. The spectrum analyzer selects automatically the number of frequency points and resolution bandwidth (RBW) at this point.

When the received signal is very small, possibly the stirrers are in such a position that the fields are almost cancelling at the reference antenna. It is advantageous to open the chamber and move the DUT slightly (in principal around a half wavelength) to another position until a strong enough signal is received while the door of the chamber is closed.

Once the radiating frequency is observed in the spectrum, one can use the “Peak Search” capability for markers. Set the center frequency equal to the frequency with the largest peak. Some spectrum analyzers have a helpful button on the panel “”MKR->CF”. The span should be narrowed around the center frequency but should not be too small avoiding the elimination of the phase noise or short term fluctuations or drift of the DUT. Due to the fast measurements, long term fluctuations of the DUT can be characterized and will result in a set of power measurements as function of time at the given radiating frequency.

In the next step the resolution bandwidth is optimized.

Center frequency = frequency with peak power, considered as radiating frequency

Resolution bandwidth

The goal is to measure the power of the DUT at the radiating frequency, resulting in one number. The resolution bandwidth needs to be selected carefully depending on what one wants to measure. Possibly one wants to eliminate sidebands from the measurements but still it is important to measure one power value at the frequency of interest. On the other hand one wants to measure the power including the phase noise and the short term fluctuations, resulting into a constant power measurement for consecutive measurements.

In zero span mode, the RBW filter (analogue or digital) filters the signal around the center frequency before amplitude or power detection.

On one hand it is important to minimize the impact of the receiver noise by reducing the RBW. The receiver noise adds up in the power measurement but is in most cases negligible. To eliminate sidebands from the measurements it can also be important to reduce the RBW.

On the other hand depending on the requirements of the measurement the RBW should include the DUT fluctuations and drift to measure the overall power.

To make this tradeoff while still in frequency-swept mode, one can observe the peak power using a marker.

Reducing the RBW, one can observe the sidebands if any around the frequency of interest. Further reduction in the RBW makes the peak amplitude drop as will be illustrated in the use case. This sets the lower limit of the RBW. Enlarging the RBW until the sidebands are not observed anymore, the power will account for the total power around the center frequency. Both cases are illustrated concretely in the use case.

The RBW should not be reduced below 1 kHz as the stirrers will create fluctuations in power which need to be measured and used to average. Otherwise the power measurement will provide wrong power values.

Resolution bandwidth (RBW) ≥ 1 kHz because of stirring

RBW set as small as possible without reducing the constant maximum power or just large enough to include DUT fluctuations and drift

Zero span mode

Once the radiating frequency and the minimal RBW are determined, the center frequency is set to the radiating frequency and the zero span mode is selected on the spectrum analyzer. The DUT is still radiating and the stirrers are not moving yet. The spectrum analyzer did select default settings for the zero span mode at this point (time span and number of points).

A constant power reading as function of time should be displayed on the screen of the spectrum analyzer. If the trace is fluctuating, these fluctuations contribute to the overall power uncertainty but are not caused by the chamber (except possibly when the chamber is not placed on a solid surface and experiences mechanical vibrations), neither the measurement principle but by the DUT behavior. Electrical drift of the DUT, fans to cool the electronics of the DUT, could also create fluctuations. It is possible to characterize these fluctuations while not stirring and subtract the equivalent power from the measurement. Presently this correction is not performed by The Wireless Connector®. One can try to reduce or enlarge the RBW to reduce the fluctuations either by filtering of the signal content causing fluctuations or by including them in the band of the RBW filter. When reducing the RBW, the power as function of time should not drop.

Depending on the type of spectrum analyzer, the center frequency in zero span mode can slightly change from the peak search reading in frequency-swept mode. Possibly the power reading in zero span mode became smaller than the reading in frequency-swept mode. In this case in zero span mode one can change the center frequency in small steps up and down to tune to a maximum constant power. This power level should be equal to the peak power in frequency-swept mode. This will be illustrated in the use case.

The power should be constant as function of time, maximum as function of center frequency and not reduce with reducing RBW. Any ripple, besides receiver noise, is contributed mainly by the DUT and ends up as inaccuracy in the TRP measurement.

Time span and Points

Up to now, the analyzer has set automatically a time span T_{span} and number of time points N_{span}, resulting in an equivalent sampling time $T_s = \frac{T_{span}}{(N_{span}-1)}$. Typically the real sampling time of the spectrum analyzer is shorter than T_s. When the average detector mode is selected, the returned result for a given multiple of T_s (kT_s) is an average power value of the underlying samples. Due to the high sampling rate compared to the field variations the underlying samples will be highly correlated. It is important to adapt the automatic spectrum analyzer settings for time span and points properly for an accurate power measurement.

The software of the Wireless Connector® collects the measurement points from the spectrum analyzer trace in zero span mode, converts to Watt and averages the power values to provide one power reading at the frequency of interest in the desired units e.g. Watt, dBm.

While the stirrers rotate, the measurements at kT_s of the changing electromagnetic field strengths should be uncorrelated and the result of a random process. Enough uncorrelated measurement samples must be collected. Based on the underlying statistics, the theoretical uncertainty on an averaged set of power measurements can be determined when the set of power measurements results from a random process (Fig. 4). For a 2σ-uncertainty of ± 0.5 dB one requires approximately 270 samples.

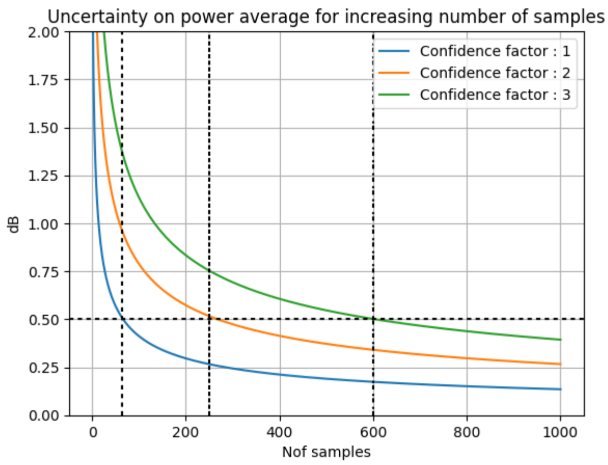

Fig. 4. Uncertainty of power average for increasing number of samples from random process

To guarantee that enough uncorrelated samples are measured, one should make sure that enough samples are taken for which the difference in stirrer rotation angle has a minimal value. Typically it means a certain timespan needs to be converted with a minimal set of points. The required minimal incremental step is given in Table 1 as function of frequency band.

Frequency band (GHz)	Minimal stirrer rotation (°)
5 - 8	20
8 - 14	10
14-20	3
20-30	1.5
> 30	1

Table 1. Minimal stirrer rotation for uncorrelated measurements as function of frequency

At lower frequencies, e.g. 8 GHz, the stirrer step between measurements should be approximately 10 degrees. If only one stirrer is rotating, one can acquire only 36 independent data points before the stirrer is back in its same position. These number of points are too low to derive power accurately. This is solved by selecting the speed of the 2 stirrers differently increasing the periodicity. When rotating the two stirrers for example respectively at 19 and 20 RPM, the periodicity will take 1 minute and the number of uncorrelated measurement points increases accordingly.

An experiment at 24.5 GHz using a Vivaldi antenna coupled to a RF generator as DUT, was performed as confirmation of the uncertainty contributed by The Wireless Connector® (Fig. 5). The spectrum analyzer is locked to the generator via the 10 MHz shared clock to guarantee the frequency reference.

Fig. 5. Vivaldi antenna mounted in The Wireless Connector®, connected to RF generator

A change in stirrer angle of 1.5 degrees to capture uncorrelated samples (Table 1) translates into 13 ms of minimal sample time for the stirrer with 19 RPM. Based on the theoretical curve (Fig. 4) one needs to collect from a random process at least 270 samples for a 2σ-uncertainty of ±0.5 dB, resulting into a time span of 3.6 s.

The experiments were performed with the SA in average detector mode with RMS power averaging during zero span mode measurement. The experiments were repeated 10 times to give a rough estimate of the precision of the power average. The experiments were performed for different RBW: 3 MHz, 30 kHz, 30 kHz. Due to the low receiver and source noise compared to the variations of the electrical fields, the RBW does not have a large influence as long as no power of the signal at fixed frequency is filtered away. Remember that the RBW should not be lower than 1 kHz to capture the field fluctuations properly.

Fig. 6 shows the 2σ-sample standard deviation on the averaged power for different RBW calculated from the uncorrelated measurements collected as function of increasing time. Appr. 270 Samples are collected over 3.5 s resulting in approximately ±0.5 dB 2σ-uncertainty. Fig. 6 shows also the theoretical curve one should expect assuming the samples are generated by a random process. Good correspondence is seen between theory and practice. In case one is sampling much faster a lot of correlated sample points are also acquired, not contributing to the statistics. The trend of the experimental curves as function of time will not change but 270 samples are acquired much faster in time. Assuming these samples would be uncorrelated the theoretical uncertainty curve drops much faster in time compared to what happens in reality, as shown in Fig. 6.

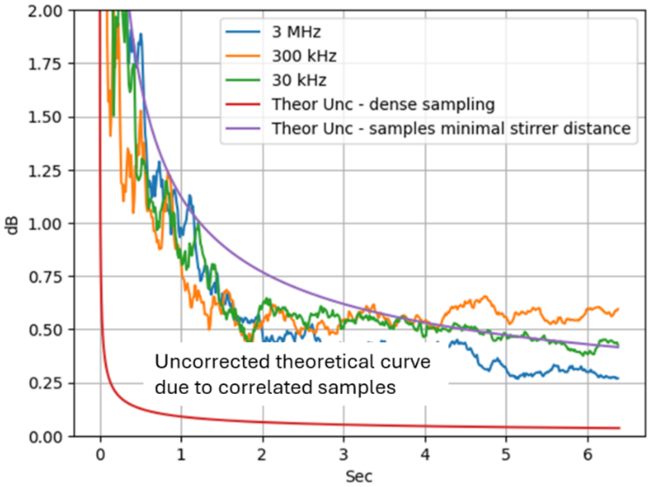

Fig. 6. Experimental and theoretical uncertainty on RMS power (24.5 GHz)

Table 1 provides minimal rotation angle Φ (deg) as function of frequency band

Fig. 4 provides for k*σ uncertainty and required precision the minimal number of sample points = N_{span}

Calculate $T_{span} = T_s(N_{span} - 1)$with $T_s = \frac{\emptyset}{6\ RPM}(s)$

The components of your calibration

Calibration is essential for obtaining absolute power levels from the measurements. The process consists of three key components, as illustrated in Fig. 7: chamber loss, antenna efficiency and the external calibration. These factors contribute to the overall signal attenuation, and their combined effect must be accounted for to obtain accurate absolute power levels, following:

$$P_{\text{corr}} = P_{\text{SA}} - G_{\text{ref}} - \eta_{\text{tot}} - G_{\text{external}}, \quad (2)$$

where P_{corr} is the corrected power in dBm or PSD in dBm/Hz depending on P_{SA}, P_{SA} is the measured power in dBm or PSD in dBm/Hz returned by the SA, G_{ref} is the chamber gain in dB, η_{tot} is the total antenna efficiency in dB and G_{external} is the gain of the external hardware in dB. Since the losses of these three factors are simply summed in log scale, it's important to note that this equation does not account for any mismatch between the antenna and external hardware, or between the external hardware and the SA. To ensure the accuracy of the calibration, these mismatches should be minimized.

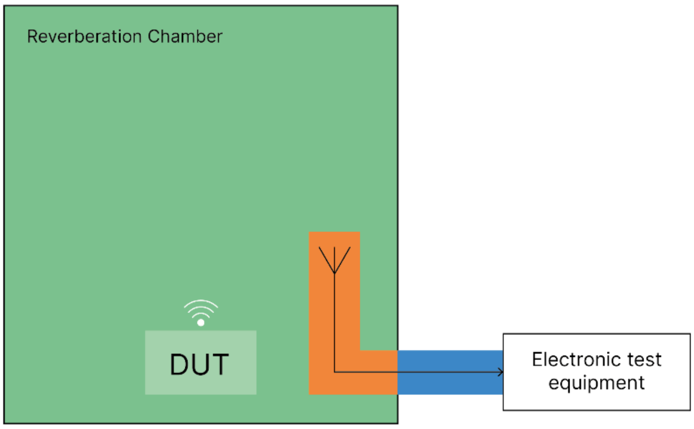

Fig. 7. Three parts of calibration: Chamber Losses (green), Antenna Efficiency (orange) and external calibration (blue)

Chamber Loss

The RC introduces inherent losses due to atmospheric attenuation and absorption by the chamber walls and stirrers. The introduction of a DUT increases this chamber loss, as the DUT alters the electromagnetic environment by adding absorption and changing the mode distribution.

To ensure accurate measurements, it is essential to characterize and compensate for the total chamber losses. This can be done in two ways [5]:

- Using the built-in calibration module together with an SA: This method performs a relative calibration, where only additional losses introduced by the DUT are measured.

These relative losses are then combined with a preloaded reference calibration to determine the total chamber loss.

- Using a Vector Network Analyzer (VNA): In this method, the total chamber loss, including both the intrinsic chamber characteristics and the DUT induced loading, is measured directly. The VNA performs an absolute measurement of the chamber in the current setup configuration.

Calibration of the chamber loss can be done using a guided wizard on the GUI [2] or through remote control, with example scripts available [3].

Antenna Efficiency

The reference antenna introduces its own losses, which must be accounted for in the calibration process. The antenna efficiency describes the ratio of received power to incident power, including all losses up to and including the connector in the reference feedthrough panel. The antenna's efficiency must be known to address this, and is typically provided by Antennex or derived from separate measurements. To ensure that the system accurately corrects for the reference antenna’s inherent losses during measurement, the losses have to be incorporated in an antenna efficiency file. This efficiency file can be updated through the chamber’s display [2] or via the remote connection [3].

External Calibration

Beyond chamber and antenna-related losses, external losses introduced by cables, waveguides, or other connection elements between The Wireless Connector® and external measurement equipment must be accounted for. These losses depend on the length, type, and frequency response of the transmission medium and can have a significant impact, especially at higher frequencies.

To accurately compensate for these losses, a separate measurement of the full external path must be performed using a VNA or similar equipment. The measured losses should then be incorporated into an external calibration file. This file can be uploaded via the chamber’s built-in display [2] or through the remote control [3], such that the system can correctly process these losses during postprocessing.

A practical example: TRP at given frequency

Introduction

For phased array antennas it is important to understand as quickly as possible whether every antenna element and complete phased array are radiating the expected total power as function of the radiation angle. In many cases one is only interested in TRP at one frequency.

As such frequency-swept spectrum analyzer measurements are overhead and instead zero span mode is used speeding up the measurement process by enabling time-dependent power measurements at a given frequency.

As example of setting up the zero span mode and performing the measurements properly, a power measurement at a specific frequency is performed for a commercially available phased array on an evaluation board (Sivers Semiconductors evaluation board "EVK06002").

The graphical user interface, provided with the Sivers software, is used to control the evaluation board. Some codebooks are provided by Sivers Semiconductors to control the beam directions at a discrete set of frequencies.

For this example the radiated frequency of 62.64 GHz is selected. At first, one must make sure to perform a chamber and external calibration at or across 62.64 GHz. It is assumed that the calibration is performed and that the DUT is positioned in the chamber after the calibration to configure the spectrum analyzer settings for zero span mode and to perform a measurement.

Initial settings

The Keysight N9030A is used in this example but the use case is not limited to this specific spectrum analyzer. With other spectrum analyzers, the specific nomenclature could be different but the concepts stay the same. One starts from a preset of the spectrum analyzer.

- The spectrum analyzer is preset
- Video bandwidth is set to maximum
- Detector mode : Average
- Average type : Power Average (RMS)

Center frequency, Resolution Bandwidth (RBW) and zero span mode

The evaluation board is put in transmit mode using the GUI of the Sivers software. From the limited set of frequencies, the radiation frequency is put to 62.64 GHz and transmit T_x is enabled (Fig. 8). One needs to wait until the device is heated up but one should avoid the temperature indicator to become red as it impacts the gain of the phased array.

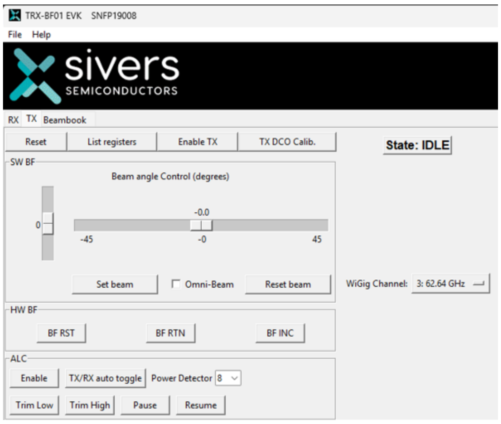

Fig. 8. Control of Sivers Phased Array "EVK06002"

- Spectrum analyzer in frequency-swept mode
- Center frequency : 62.64 GHz and span 10 MHz
- Peak search with marker and center frequency set to radiating frequency
- If peak amplitude very low, open The Wireless Connector® and change location of DUT slightly (in principal around a half wavelength) for higher peak power when the door is closed
- If one does not want to include sidebands in the TRP measurement in zero span, reduce RBW to visualize possible sidebands. RBW = 91 kHz (selected by spectrum analyzer), Peak value = -40.3 dBm (Fig. 9)

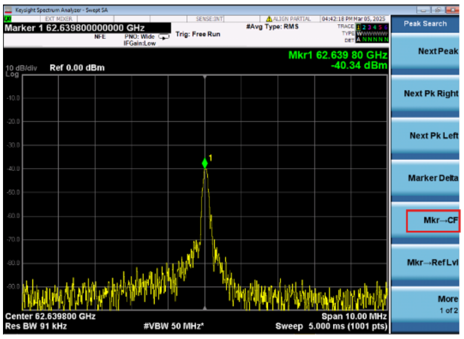

Fig. 9. RBW reduction to avoid presence of sidebands in measurement

- Reduce RBW to identify lower limit until peak power starts to reduce but RBW should be larger than 1 kHz to capture the stirring effects. RBW = 3.3 kHz, Peak value = -44.4 dBm (Fig. 10)

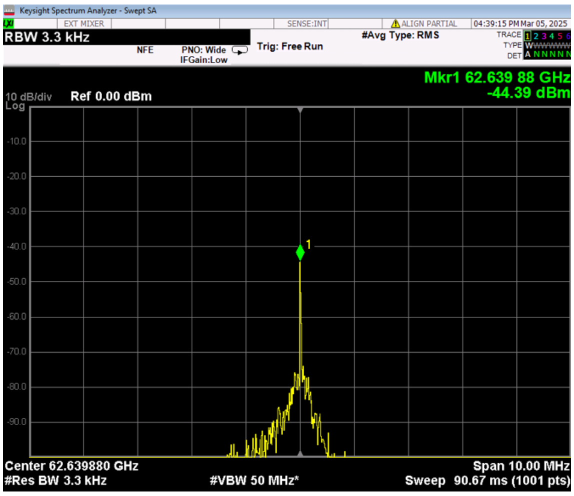

Fig. 10. Reduction in RBW causes reduction in peak power

- If one wants to include frequency drift, fluctuations, phase noise in the TRP measurement, the RBW should be set just large enough to include these effects. RBW = 1 MHz, Peak value = -40.5 dBm (Fig. 11)

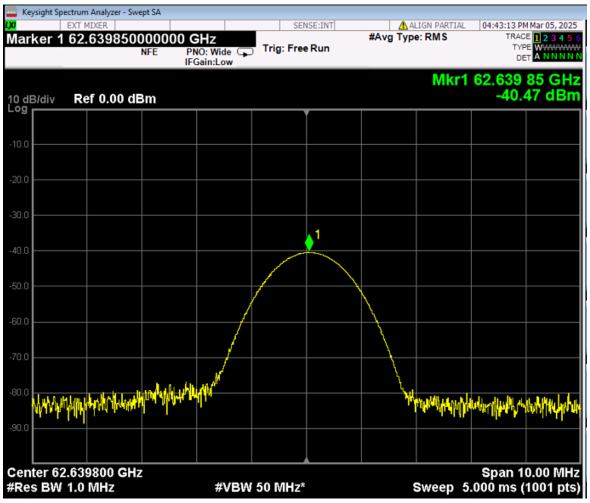

Fig. 11 RBW selected to include sidebands

- Decide on what TRP measurement is required: either focus on the peak amplitude avoiding sidebands or include the sidebands. Select the RBW accordingly.
- Update peak search marker to maximum power and update center frequency to the frequency at the maximum power
- Switch to zero span mode. A straight line should be observed as function of time if the DUT is stable. Adjust center frequency in small steps up and down to reach the maximum power observed in the frequency-swept mode. The stirrers are not moving yet.

Fig. 12. Zero span mode after tuning center frequency, no stirring

- Adapt timespan (3.5 s) and number of points (minimal 270 pts)
- Any power fluctuations as function of time will be included in the power measurement. One needs to decide whether these fluctuations should be part of the power measurement or measures need to be taken to avoid these fluctuations.
- Save the advanced spectrum analyzer settings, which need to be applied during measurements, with the GUI or via the remote control capability of The Wireless Connector® software
- Make sure a calibration was performed already including the desired frequency

Power Measurement

- Make sure the DUT is put in the proper state and radiating
- Activate the stirrers as mentioned above
- Use either the GUI or the remote control capability of The Wireless Connector® to determine the power for the given DUT state at given frequency based on the advanced settings of the spectrum analyzer and the adapted settings of the continuous stirring stirrers

The uncertainty provided by the software is the sample standard deviation on the average of the power across all samples. It includes all the fluctuations during the capturing of the signal by the spectrum analyzer: the receiver noise, the uncertainty from the random process created in the reverberation chamber by the stirring and the sampling, the drift of or changes in the component. It does not contain any systematic errors, e.g. any power errors introduced during the calibration process.

The zero span mode enables fast characterization of the power or TRP performance of phased arrays at a given frequency using The Wireless Connector®. Fig. 13 illustrates an example of the measurement of the TRP for a phased array, radiating at 62.64 GHz, stepping the beam direction from -44 degree to 44 degree. Fig. 13 shows the result of 5 repeated measurements and their mean power as function of the radiation angle. The measurement repeatability, achieved with The Wireless Connector® can be clearly distinguished from the variation of radiated power as function of radiation angle of the phased array. The overall 2σ-uncertainty in Fig. 13 is ± 0.3 dB.

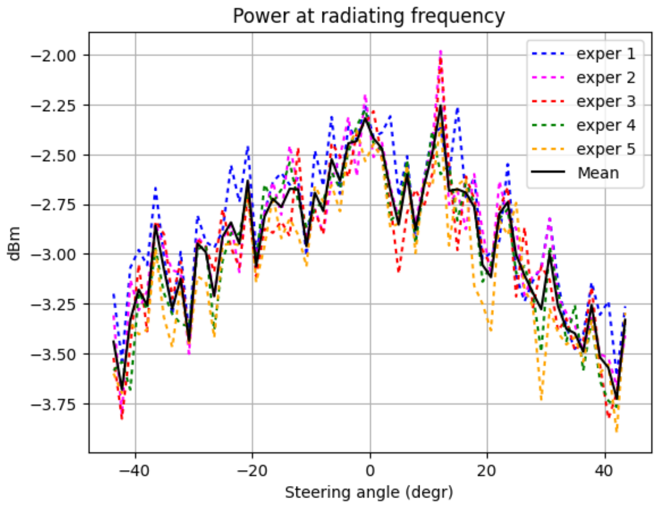

Fig. 13. Example of TRP measurement for different beam positions (2σ = ± 0.3 dB)

Summary

In contrast to the anechoic chamber, The Wireless Connector®, based on a reverberation chamber, provides the advantage of easy, accurate and fast power characterization of active phased array antennas or any other radiation device. For phased array antennas one is often interested in the TRP of one, more or all antenna elements at one given frequency while possibly changing the beam direction. As such phased array antenna characterization benefits from the zero span mode of spectrum analyzers in combination with continuous stirring.

The application note described the configuration of a spectrum or vector signal analyzer in zero span mode, sampling randomly the changing electromagnetic fields while the stirrers rotate continuously.

To perform absolute power measurements it is crucial to perform a calibration at or across the frequency of interest. The TRP measurements can be performed via the interactive interface on the screen of The Wireless Connector® or via the provided remote control capability, enabling efficient measurement automation for different DUT settings. This makes it an ideal tool for design, design validation and integration into the production process.

References

[1] “Performing spectrum measurements using The Wireless Connector®”, Application Note, Antennex, 2025

[2] “User Manual – The Wireless Connector®”, Advanced Settings, Antennex, 2025

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[4] “A Guide To Antenna Measurements in mmWave Reverberation Chambers”, Anouk Hubrechsen, Phd. TU Eindhoven, 26 Oktober 2023, p. 27

[5] "Calibration Techniques for The Wireless Connector®", Application Note, Antennex, to be released in April 2025

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